

**Phytoplankton Production, as Estimated by
the C¹⁴ Technique, and Populations
Contributing to Production 1980/81/82, in
the Turkey Lakes, Ontario, Watershed.**

R.H.Collins, J.R.M.Kelso, J.H.Lipsit
Great Lakes Fisheries Research Branch,
1219 Queen Street East,
Sault Ste. Marie, Ontario. P6A 5M7
and

J.E.Moore,
Great Lakes Fisheries Research Branch,
867 Lakeshore Road,
Burlington, Ontario. L7R 4A6

August 1983

**Canadian Technical Report of
Fisheries and Aquatic Sciences
No.1191**

Canadian Technical Report of Fisheries and Aquatic Sciences

These reports contain scientific and technical information that represents an important contribution to existing knowledge but which for some reason may not be appropriate for primary scientific (i.e. *Journal*) publication. Technical Reports are directed primarily towards a worldwide audience and have an international distribution. No restriction is placed on subject matter and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries management, technology and development, ocean sciences, and aquatic environments relevant to Canada.

Technical Reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report will be abstracted in *Aquatic Sciences and Fisheries Abstracts* and will be indexed annually in the Department's index to scientific and technical publications.

Numbers 1-456 in this series were issued as Technical Reports of the Fisheries Research Board of Canada. Numbers 457-714 were issued as Department of the Environment, Fisheries and Marine Service, Research and Development Directorate Technical Reports. Numbers 715-924 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Technical Reports. The current series name was changed with report number 925.

Details on the availability of Technical Reports in hard copy may be obtained from the issuing establishment indicated on the front cover.

Rapport technique canadien des sciences halieutiques et aquatiques

Ces rapports contiennent des renseignements scientifiques et techniques qui constituent une contribution importante aux connaissances actuelles mais qui, pour une raison ou pour une autre, ne semblent pas appropriés pour la publication dans un journal scientifique. Il n'y a aucune restriction quant au sujet, de fait, la série reflète la vaste gamme des intérêts et des politiques du Ministère des Pêches et des Océans, notamment gestion des pêches, techniques et développement, sciences océaniques et environnements aquatiques, au Canada.

Les Rapports techniques peuvent être considérés comme des publications complètes. Le titre exact paraîtra au haut du résumé de chaque rapport, qui sera publié dans la revue *Aquatic Sciences and Fisheries Abstracts* et qui figurera dans l'index annuel des publications scientifiques et techniques du Ministère.

Les numéros 1-456 de cette série ont été publiés à titre de Rapports techniques de l'Office des recherches sur les pêcheries du Canada. Les numéros 457-714, à titre de Rapports techniques de la Direction générale de la recherche et du développement, Service des pêches et de la mer, ministère de l'Environnement. Les numéros 715-924 ont été publiés à titre de Rapports techniques du Service des pêches et de la mer, Ministère des Pêches et de l'Environnement. Le nom de la série a été modifié à partir du numéro 925.

La page couverture porte le nom de l'établissement auteur où l'on peut se procurer les rapports sous couverture cartonnée.

PHYTOPLANKTON PRODUCTION, AS ESTIMATED BY THE C^{14} TECHNIQUE,
AND POPULATIONS CONTRIBUTING TO PRODUCTION 1980/81/82, IN
THE TURKEY LAKES, ONTARIO, WATERSHED

by

R.H. Collins, J.R.M. Kelso, J.H. Lipsit

Great Lakes Fisheries Research Branch

1219 Queen Street East

Sault Ste. Marie, Ontario

P6A 5M7

and

J.E. Moore

Great Lakes Fisheries Research Branch

867 Lakeshore Road

Burlington, Ontario

L7R 4A6

(c) Minister of Supply and Services Canada 1983

Cat. No. Fs 97-6/1191

ISSN 0706-6457

Collins, R.H., J.R.M. Kelso, J.H. Lipsit & J.E. Moore. 1983. Phytoplankton production, as estimated by the C^{14} technique, and populations contributing to production 1980/81/82, in the Turkey Lakes, Ontario, Watershed. Can. Tech. Rep. Fish. Aquat. Sci., (1191).

ABSTRACT

The Turkey Lakes calibrated watershed consists of a series of four lakes (five basins) underlain by sparingly soluble silicate bedrock. Lowest pH's and alkalinities occurred in the headwater lake and increased downstream. Carbon assimilated (measured by in situ C^{14} incubation) was greatest between one and four metres in all lakes. Production was low in winter, $<0.5 \text{ mg C m}^{-3} \text{ h}^{-1}$, and increased during summer. Carbon assimilated in the ice-free period was greatest in the shallowest lake and lower in the larger, deeper lakes of the watershed. Production followed the order imposed by lake depth. The headwater lake did not develop the bloom/crash change in phytoplankton abundance or species composition that occurred in all the other lakes. Peaks in production coincided with peaks of algal abundance. Cyanophytes were consistently the dominant algal group with the species contributing to peaks in phytoplankton abundance varying from lake to lake.

Collins, R.H., J.R.M. Kelso, J.H. Lipsit, & J.E. Moore. 1983. Production de phytoplancton estimée au moyen de la méthode du C^{14} et populations contribuant à la production pour 1980, 1981, et 1982 dans le bassin versant des lacs Turkey en Ontario. Can. Tech. Rep. Fish. Aquat. Sci., (1191).

RESUME

Le bassin versant étalonné des lacs Turkey se compose d'un semble de quatre lacs (cinq bassins) et repose sur un socle rocheux silicaté faiblement soluble. Les pH et les alcalinités les plus faibles sont observés dans le lac d'amont et augmentent vers l'aval. La quantité de carbone assimilé (mesurées par incubation in situ du C^{14}) était la plus grande entre un et quatre mètres dans tous les lacs. La production était faible en hiver, moins de $0.5 \text{ mg C m}^{-3} \text{ g}^{-1}$, et augmentait pendant l'été. La quantité de carbone assimilé pendant la période sans glace était la plus forte dans le lac le moins profond et la plus faible dans les lacs plus grands et plus profonds du bassin versant. Le lac d'amont ne présentait pas les modifications marquées de la productivité ou la diversité des espèces caractéristiques du phytoplancton dans tous les autres lacs. Les maximums de la production coïncidaient avec les périodes de plus grande abondance des algues. Les cyanophytes constituaient uniformément le groupe d'algues dominant et les espèces responsables des maximums d'abondance du phytoplancton variaient d'un lac à l'autre.

INTRODUCTION

Acid deposition is high (20 to 70 mg $\text{SO}_4 \text{ m}^{-2} \text{yr}^{-1}$) over much of the sensitive Canadian Shield (Harvey et al., 1981) and threatens sensitive lakes in Ontario (Kelso & Minns, 1982; Minns, 1981). Correlative observation suggests that acidification either significantly decreases phytoplankton species diversity (Kwiatkowski & Roff, 1976) or produces only a marginal influence (Kelso et al., 1982) upon community structure. Müller (1980) has also shown that changes occurred in the periphyton community of an Ontario lake during artificial acidification. The effects of acidification upon primary production is less clear (Conway & Hendrey, 1982) and the mechanisms have been surmised rather than determined experimentally (Johnson, 1982).

This paper does not deal with production changes resulting from the acidification process, but examines the change in carbon incorporation of natural phytoplankton in situ within a watershed which progresses from a poorly buffered first order lake downstream through progressively better buffered systems.

LAKE DESCRIPTIONS

The watershed (Fig. 1) is situated some 50 km north of Sault Ste. Marie, Ontario, and some 25 km east of Coppermine Point on Lake Superior. No local sources of anthropogenic contamination are implicated in the chemical state of the system. The Turkey Lakes are a series of four lakes (five basins) which originate from a poorly buffered ($36 \mu\text{eq l}^{-1}$), low pH (5.9), first order lake. The watershed is completely underlain by sparingly soluble silicate bedrock (greenstones and granites). Alkalinity within the watershed increases to a high of about $190 \mu\text{eq l}^{-1}$ in Big Turkey Lake (Table 1).

Batchawana Mountain (elevation 628 m) dominates the watershed and falls away to Turkey Lake (elevation 372 m) with an overall relief of 256 m. Individual lake elevations for each basin are, L1 - 497 m, L2 - 497 m, L3 - 388 m, L5 - 375 m, and L6 - 372 m.

Measurements to assess primary productivity in the Turkey Lakes watershed study commenced as soon as the lakes were free of ice during April-May in the spring, and continued to October-November each year. The method chosen was the C^{14} technique and incubations coincided with maximum solar input at mid-day. Breaks in sampling (June, August-October, 1980) were unavoidable due to impassable road conditions, personnel change, and equipment malfunctions. Incubations were conducted on a bi-weekly basis throughout the ice-free period in all five lakes. Two teams were used so that all incubations were coincident.

A buoy with a suspension apparatus was placed in each lake as soon as the ice disappeared in the spring and left in place until freeze-up. Incubations were carried out in 125 ml reagent bottles at surface, one, two, three, and five metres with the exception of L3 where the lake was only four metres deep. Water was collected from the appropriate depth using a three-litre horizontal Van Dorn sampler. All bottles were rinsed three times with the sample water. For each depth, two bottles were filled with ambient water and one ml of water withdrawn to allow for the addition of a C^{14} solution. The bottles were inoculated with 100 μ l of C^{14} , then capped, and suspended at their appropriate depths immediately. For a background count, one extra bottle from the greatest depth was treated identically except that all light was excluded.

Incubation time was dependent on light intensity, varying from two hours on a clear sunny day to four hours on an overcast fall day. After the allotted time elapsed, samples were retrieved and incubation time was noted. Each sample

was fixed with one ml of a 37 percent formaldehyde solution and capped for transport.

A 100 ml aliquot of each bottle was filtered through a 0.45 μ cellulose membrane filter at less than seven p.s.i. vacuum. Each filter was placed in a 25 ml scintillation vial and 20 ml of PCS scintillation cocktail added. All counts were made using a liquid scintillation counter.

Test incubations with water screened through a 64 μ mesh showed no significant difference in carbon incorporation from untreated water samples and screening was therefore discontinued.

Total carbon uptake for each depth was calculated using the mean of the duplicate counts and subtracting the background count determined from the dark bottle:-

$$^{12}\text{Cu} = 1,000 \times \frac{^{12}\text{C}_A}{^{14}\text{C}_A} \times \frac{^{14}\text{Cu}}{T} \times 1.06 \times \frac{1}{S} \times B$$

where ^{12}Cu = carbon uptake rate in $\text{mg C m}^{-3} \text{ h}^{-1}$

$^{12}\text{C}_A$ = total dissolved inorganic carbon (DIC) in mg l^{-1} (Fig. 5)

^{14}Cu = DPM uptake (count result)

$^{14}\text{C}_A$ = DPM added to bottle

T = incubation time (hours)

B = bottle volume (125 ml)

S = filtered volume (100 ml)

Phytoplankton were identified and counted using the Utermöhl inverted microscope technique (Vollenweider, 1969). Collection methods and times were similar to those described below for water.

Alkalinity and pH values were determined from tube composite samples. Total DIC was determined by comparison of DIC values to alkalinity (R. Semkin, unpublished).

Surface temperatures were obtained from an electronic bathythermograph (R. Semkin, unpublished).

Light intensity measurements were obtained from a solarimeter and are expressed in Langleys per hour.

RESULTS AND DISCUSSION

In the five basins of the watershed, lowest pH's (Fig. 2) were consistently found in L1 and increased downstream where the highest pH's were consistently found in L6 (Table 1). A regular progressive downstream increase of at least one unit of pH is apparent. In 1981, pH's were highest in late summer and lowest in May. In 1980, pH's were highest in early summer and lowest in May. In summers of both years, pH's were similar.

Temperatures varied only slightly among the lakes and followed the expected annual cycle for lakes in this latitude (Fig. 3). Maximum temperature (26 to 27°C) occurred in mid-July in 1981 and in June in 1980. Minimum temperatures occurred, of course, during the winter. Ice formed during the period late October to early November in both years and disappeared in the first week in May. The shallowest lake, L3, was always slightly warmer than other lakes in the system.

Solar radiation (Fig. 4) varied between 150 and 600 Langleys during both years. Minimum values occurred in the fall during these incubation series.

Data in Fig. 5 were from all lakes and no apparent difference in the DIC-alkalinity relationship is apparent. Dissolved inorganic carbon was linearly related to alkalinity and the correlation coefficient was high ($r = 0.85$) and significant at $P = < .05$.

All basins within the Turkey Lakes system were poorly buffered, having alkalinities of $< 200 \mu\text{eq l}^{-1}$. By comparison with other lakes on the Canadian

Shield, these lakes are similar to those typically found on resistant substrate but are among the most poorly buffered systems (Kelso et al., 1982). This type of lake reflects those which typically undergo large seasonal shifts in pH and alkalinity resulting from spring freshets (Jeffries et al., 1979).

Carbon assimilation varied with depth in each lake with maximum production consistently between one and four metres (Table 2). For comparative purposes among the lakes, only the maximum production ($P_{\max}$) was used, regardless of the depth at which it occurred. Carbon assimilation by the phytoplankton assemblage was extremely limited, $< 0.5 \text{ mg m}^{-3} \text{ h}^{-1}$, both under ice cover and in early spring (Fig. 6) in all lakes.

Production increased during summer (Fig. 6) and although the increase was irregular in nature, the peaks are apparent. The magnitude of the peaks in production was greatest in L3. Carbon assimilated was also greatest in L3 with large, well-defined peaks in plankton production apparent. Conversely, production was usually lower in the larger and deeper L6, with the exception of some observed periods of low production in L1 and L2 during 1981.

Production followed the order imposed by lake depth (L3 L2 L1 L5 L6). No nutrient data is available at this time for this system and thus the influence of nutrient availability on phytoplankton production cannot be examined.

During 1980, Cyanophytes were the dominant contributors to the number of species in all lakes (Figs. 7 to 11). Merismopedia punctata Meyen was the major blue-green in L1 and L2 and became the sole Cyanophyte species during the summer peak period of production and thus was the dominant algae. These lakes (L1 and L2) never developed the bloom/crash change in abundance or species that occurred in the other lakes. In L3 the same species was significant but blooms were coincident with species dominance changes and blooms of Microcystis flos-aquae

(Wittrock) Kirchn. in early August. In late September, blooms were associated with increased numbers of a wider variety of species such as Aphanothece clathrata West & G.S. West, Chroococcus dispersus (Keissl.) Lemm. and Anabaena solitaria Kleb. Species shifts within L5 also accounted for the peaks in algal abundance. Chroococcus were always a major contributor, but the peaks were coincident with increased number of Aphanothece clathrata in July, Microcystis in August and mid-September, and Coelosphaerium minutissimum Lemm. at the end of September. Several species contributed to the community in L6 with Chroococcus dispersus playing a major role in the summer bloom along with Aphanothece clathrata. The fall bloom was produced by Merismopedia punctata.

When production is low during the colder months, no major species are dominant and the total number of cells, <1,000 cells per ml, is composed of Chrysophyceae, Bacillariophyceae, Chlorophyta, Pyrrhophyta, and Cyanophyta. Since the collections of Kelso et al. (1982) were made in the colder months, the species discussed there are typical of low production periods.

ACKNOWLEDGEMENTS

This work was initiated by R.J. Love in 1980. A number of persons assisted with field work over the years including particularly K. Thomas, M.-A. Miltenberg, D. Prescott, G. Reider, and J. Kraft. Much of the background lake characteristics were provided by R. Semkin, National Water Research Institute, Environment Canada.

REFERENCES

- Conway, H.L., & Hendry, G.R. 1982. "Ecological effects of acid precipitation on primary producers." In: F.M. D'Itri (ed.), 'Acid Precipitation: Effects on Ecological Systems': 277-295. Ann Arbor Sci. Publ., Michigan.
- Harvey, H.H., Pierce, R.C., Dillon, P.J., Kramer, J.R., & Whelpdale, D.M. 1981. "Acidification in the Canadian aquatic environment: scientific criteria for assessing the effects of acidic deposition on aquatic ecosystems." Nat. Res. Council of Can. Rep. NRCC No. 18475. 369 p.
- Jeffries, D.S., Cox, C.M., & Dillon, P.J. 1979. "Depression of pH in lakes and streams in central Ontario during snowmelt." J. Fish. Res. Bd. Can., 36: 640-646.
- Johnson, M.G. 1982. "Acid rain and fisheries - an overview." In: 'Acid Rain/Fisheries': 329-339. Amer. Fish. Soc., Maryland.
- Kelso, J.R.M., Love, R.J., Lipsit, J.H., & Dermott, R. 1982. "Chemical and biological status of headwater lakes in the Sault Ste. Marie District, Ontario." In: F.M. D'Itri (ed.), 'Acid Precipitation: Effects on Ecological systems': 165-207. Ann Arbor Sci. Publ., Michigan.
- Kelso, J.R.M., & Minns, C.K. 1982. "Current status of lake acidification and its effect on the fishery resources of Canada." In: 'Acid Rain/Fisheries': 69-81. Amer. Fish. Soc., Maryland.
- Kwiatkowski, R.E., & Roff, J.C. 1976. "Effects of acidity on the phytoplankton and primary productivity of selected northern Ontario lakes." Can. J. Bot., 54: 2546-2561.
- Minns, C.K. 1981. "Acid rain: a preliminary estimate of the risk to Ontario's inland fisheries." Can. MS Rept. Fish. Aquat. Sci., (1622).

- Müller, P. 1980. "Effects of artificial acidification on the growth of periphyton." *Can. J. Fish. Aquat. Sci.*, 37: 355-363.
- Vollenweider, R.A. 1969. "A manual on methods for measuring primary production in aquatic environments." International Biological Programme, Blackwell Scientific Publications, Oxford.

List of Tables

Table 1. Lake morphometric and chemical characteristics (annual mean values) of lakes in the Turkey Lakes watershed (Jeffires and Semkin, 1982).

Table 2. Carbon incorporation measured in situ in the Turkey Lakes watershed on three representative dates, June 9, August 11, and September 8, 1982.

Table 1. Lake morphometric and chemical characteristics (annual mean values) of lakes in the Turkey Lakes Watershed (Jeffries and Semkin, 1982).

Lake	Elevation (m)	Lake Area (ha)	Drainage Basin Area (ha)	Alkalinity ($\mu\text{eq l}^{-1}$)		pH		Conductivity	
				1980	1981	1980	1981	1980	1981
Batchawana									
N. Basin (L1)	497	5.88	24.0	38	35	6.33	5.47	27.47	31.53
Batchawana									
S. Basin (L2)	447	5.82	61.7	61	46	6.33	5.47	31.61	33.86
Wishart									
(L3)	388	19.2	337	107	99	6.83	6.18	39.34	45.09
Little Turkey									
(L5)	375	19.2	491	156	128	7.02	6.39	45.04	48.46
Turkey									
(L6)	372	52.0	803	188	167	7.07	6.55	47.79	53.01

Table 2. Carbon incorporation measured in situ in the Turkey Lakes watershed on three representative dates June 9, August 11, and September 8, 1982.

Incubation depth	Batchawana L.			Wishart L.			Little Turkey L.			Big Turkey L.					
	June 9/82	Aug. 11/82	Sept. 8/82	June 9/82	Aug. 11/82	Sept. 8/82	June 9/82	Aug. 11/82	Sept. 8/82	June 9/82	Aug. 11/82	Sept. 8/82			
0	1.5	1.1	3.4	1.6	4.9	4.9	2.0	1.6	4.2	0.8	1.4	1.5	0.9	1.4	1.7
1	2.2	2.0	3.7	1.5	4.8	4.6	2.4	4.6	4.1	0.9	2.7	2.0	1.4	1.7	2.2
2	2.6	3.2	2.8	1.5	4.5	4.1	2.9	7.1	4.0	1.1	3.8	2.9	1.6	2.2	2.9
3	2.1	3.0	3.0	1.3	4.5	3.1	3.4	6.7	3.1	1.3	3.4	3.4	1.4	2.5	2.7
4	1.4	2.5	2.5	0.7	4.1	2.1	1.8	3.5	1.7	1.5	2.8	3.2	1.3	2.5	2.5
5	1.0	2.2	0.6	0.5	2.8	1.9				1.6	2.4	3.1	1.5	2.4	2.6

List of Figures

- Fig. 1. - Boundary and Sub-basin Boundaries for the Turkey Lakes Watershed, and the location of lakes 1 to 6.
- Fig. 2. - pH Levels during incubation times for 1980 and 1981 in the Turkey Lakes watershed.
- Fig. 3. - Surface Temperatures during incubation times for 1980 and 1981 in the Turkey Lakes watershed.
- Fig. 4. - Solar Radiation during incubation times for 1980 and 1981 in the Turkey Lakes watershed.
- Fig. 5. - Turkey Lakes data, dissolved inorganic carbon versus alkalinity, tube samples only.
- Fig. 6. - Carbon assimilated ($\text{mg m}^{-3} \text{ h}^{-1}$ per lake) 1980/81/82 as determined from C_{14} in situ incubations.
- Fig. 7. - Seasonal changes in phytoplankton composition for Lake L1, 1980.
- Fig. 8. - Seasonal changes in phytoplankton composition for Lake L2, 1980.
- Fig. 9. - Seasonal changes in phytoplankton composition for Lake L3, 1980.
- Fig. 10 - Seasonal changes in phytoplankton composition for Lake L5, 1980.
- Fig. 11 - Seasonal changes in phytoplankton composition for Lake L6, 1980.

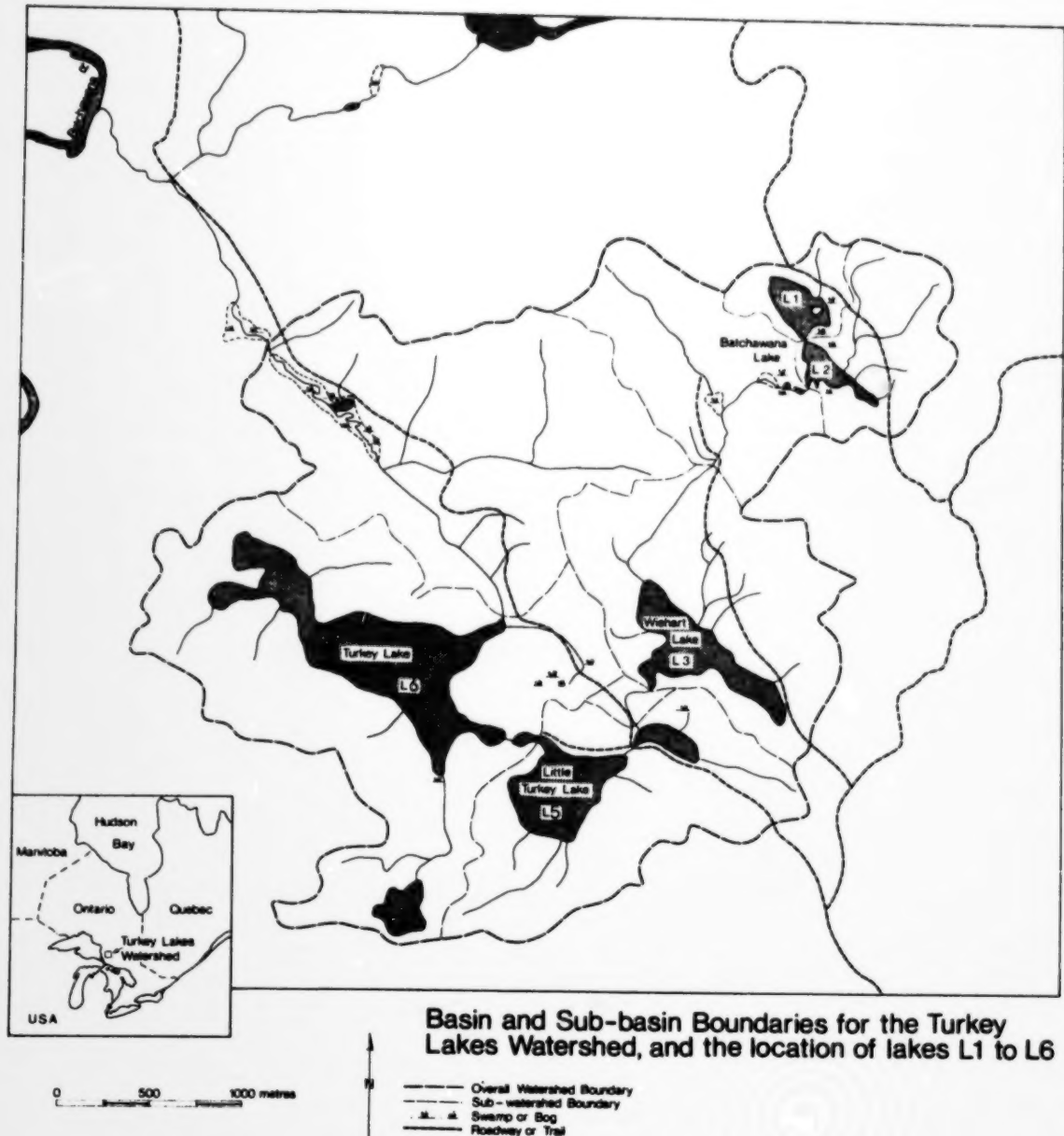


Fig. 1.

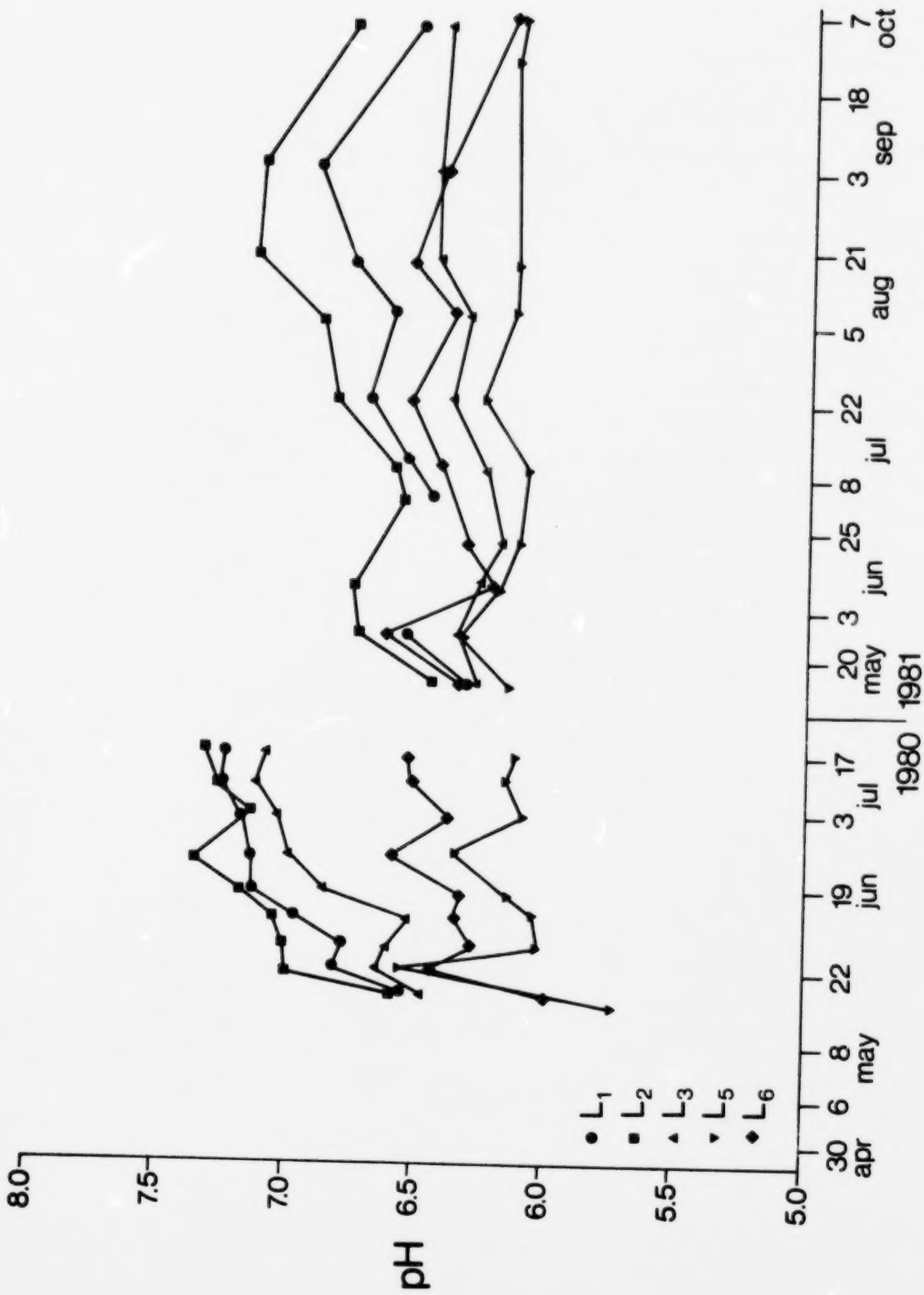


Fig. 2. pH levels during incubation times for 1980 and 1981 in the Turkey Lakes watershed.

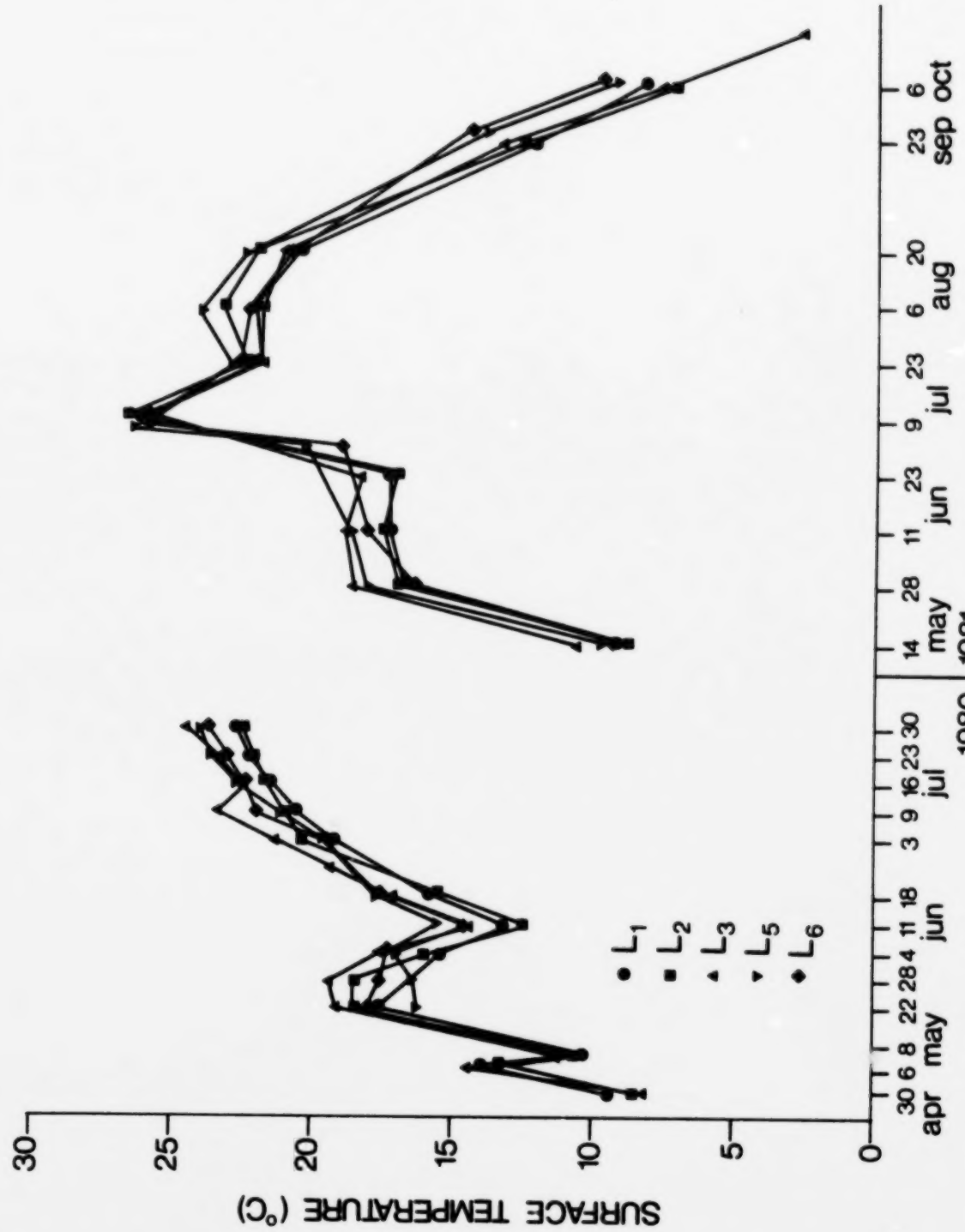


Fig. 3. Surface temperatures during incubation times for 1980 and 1981 in the Turkey Lakes Watershed.

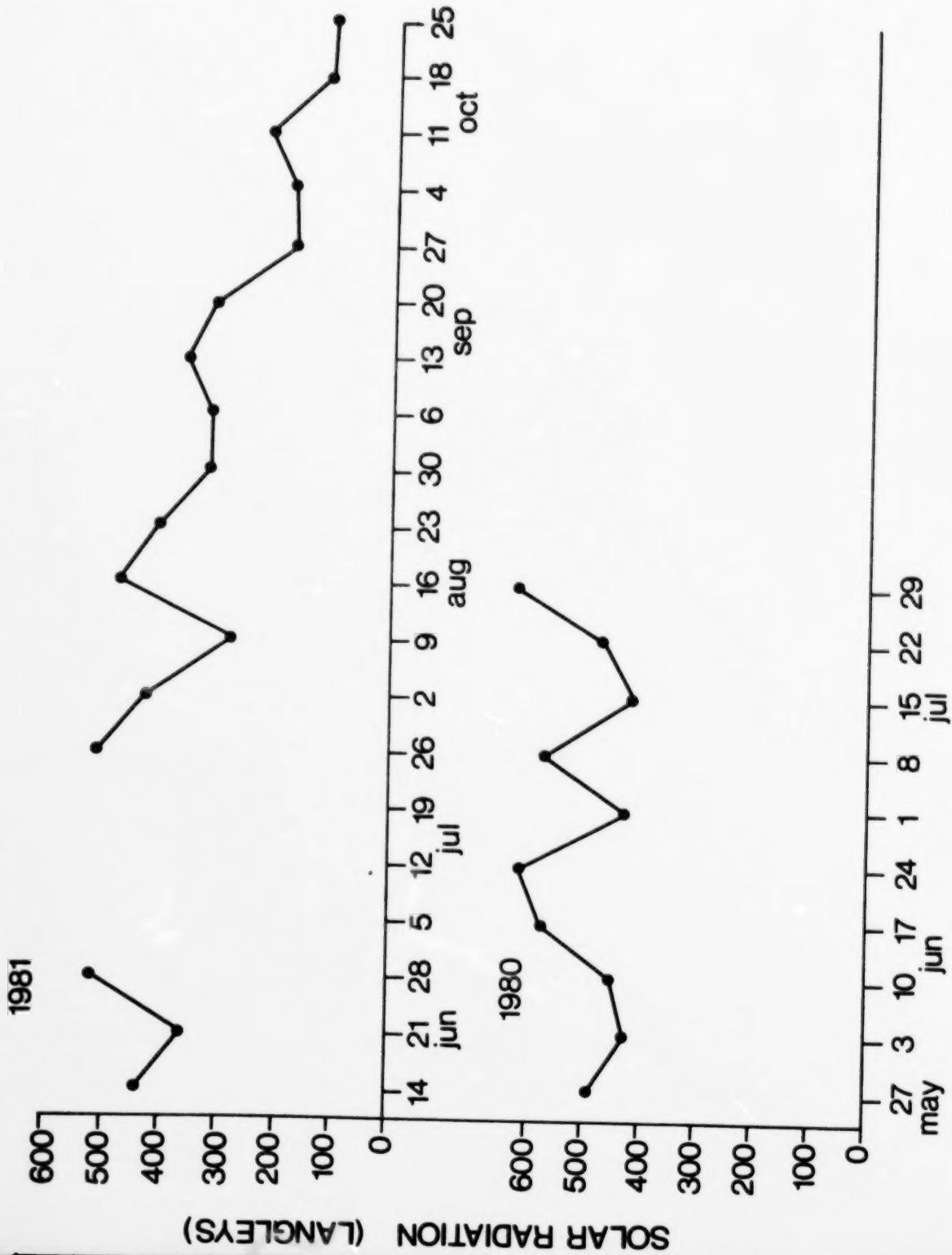


Fig. 4. Solar radiation during incubation times for 1980 and 1981 in the Turkey Lakes watershed.

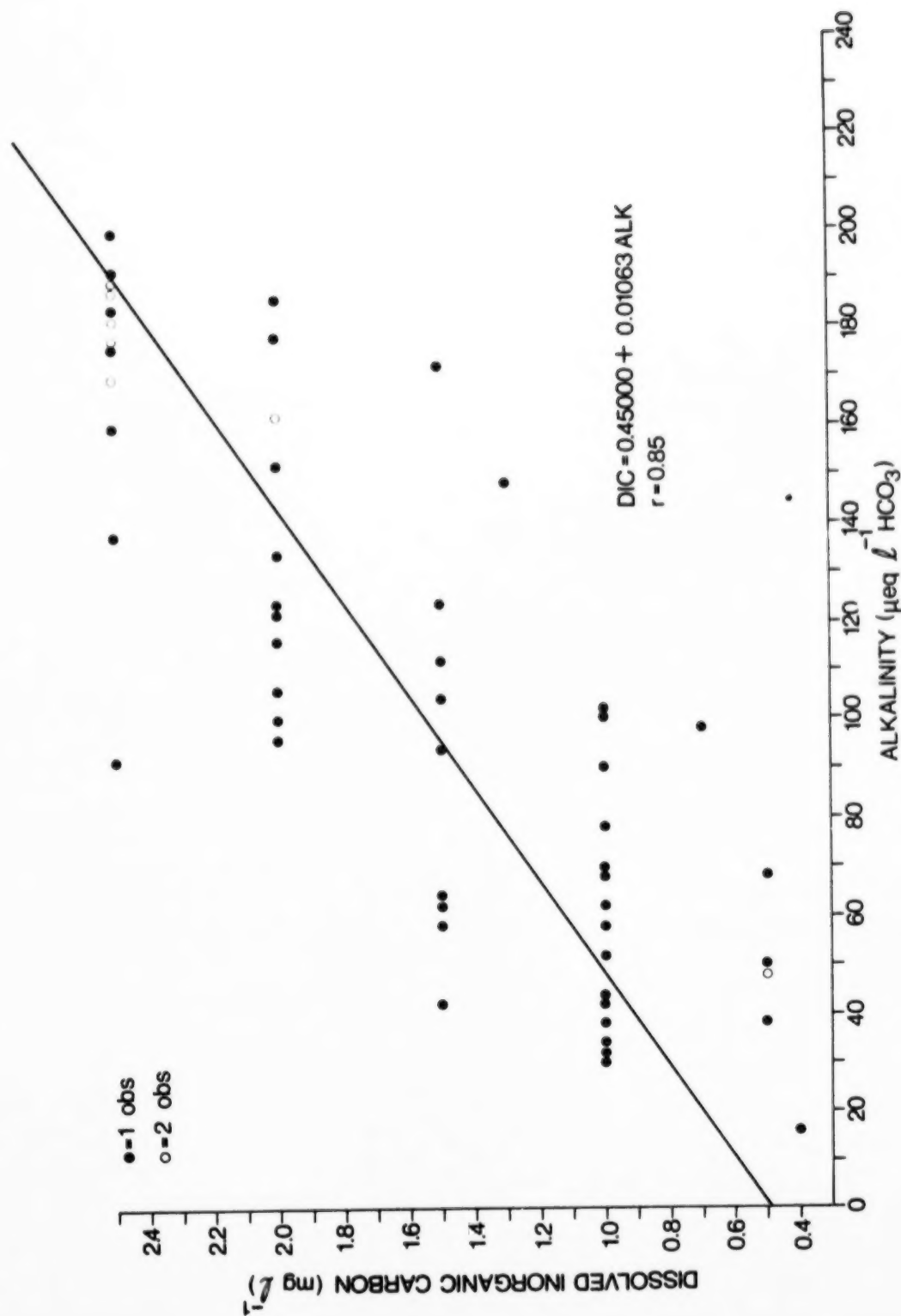


Fig. 5. Turkey Lakes Data, Dissolved Inorganic Carbon versus Alkalinity, tube samples only

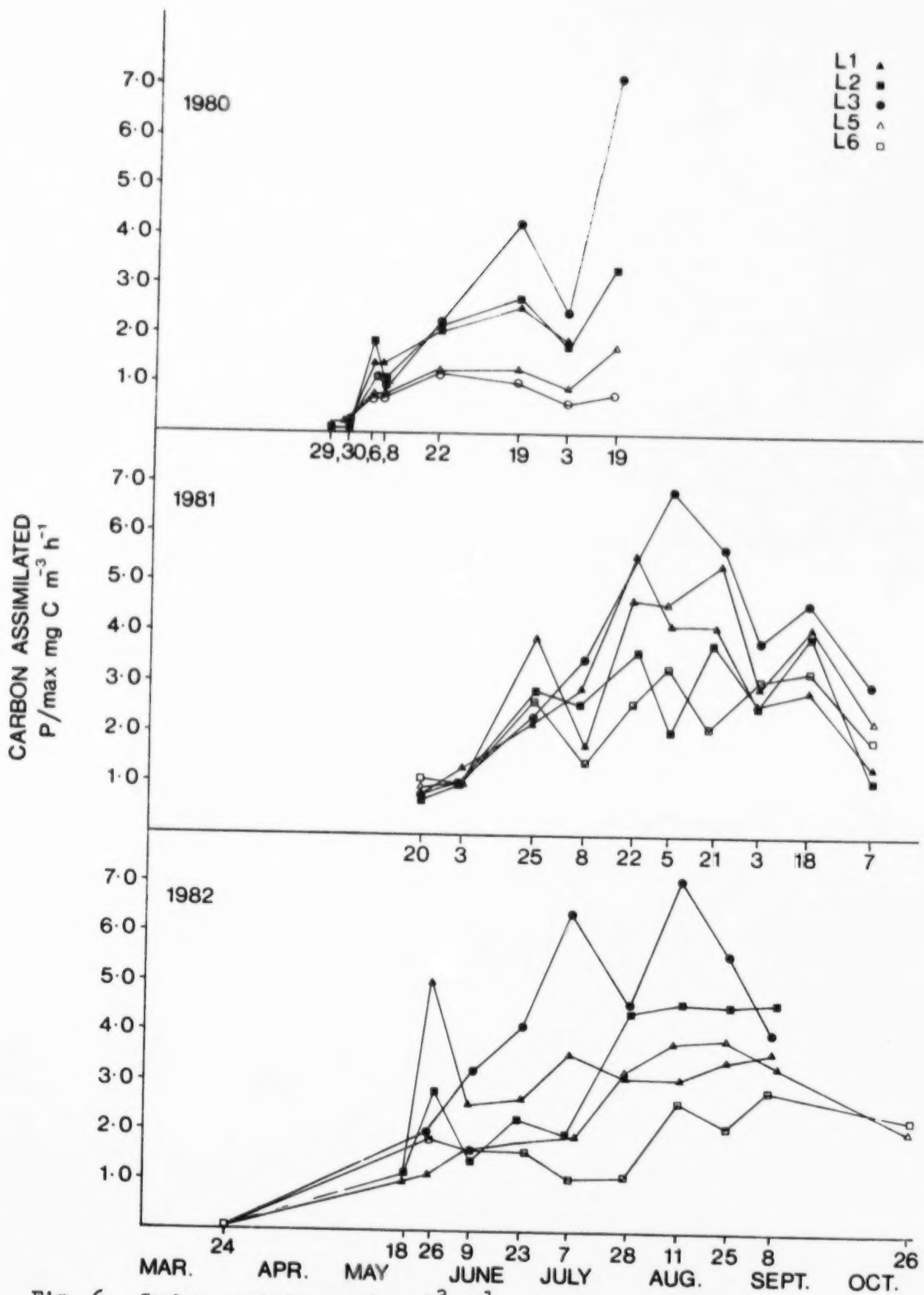


Fig. 6. Carbon assimilated ($\text{mg m}^{-3} \text{ h}^{-1}$ per lake) for 1980, 1981, and 1982 as determined from C_{14} in situ incubations.

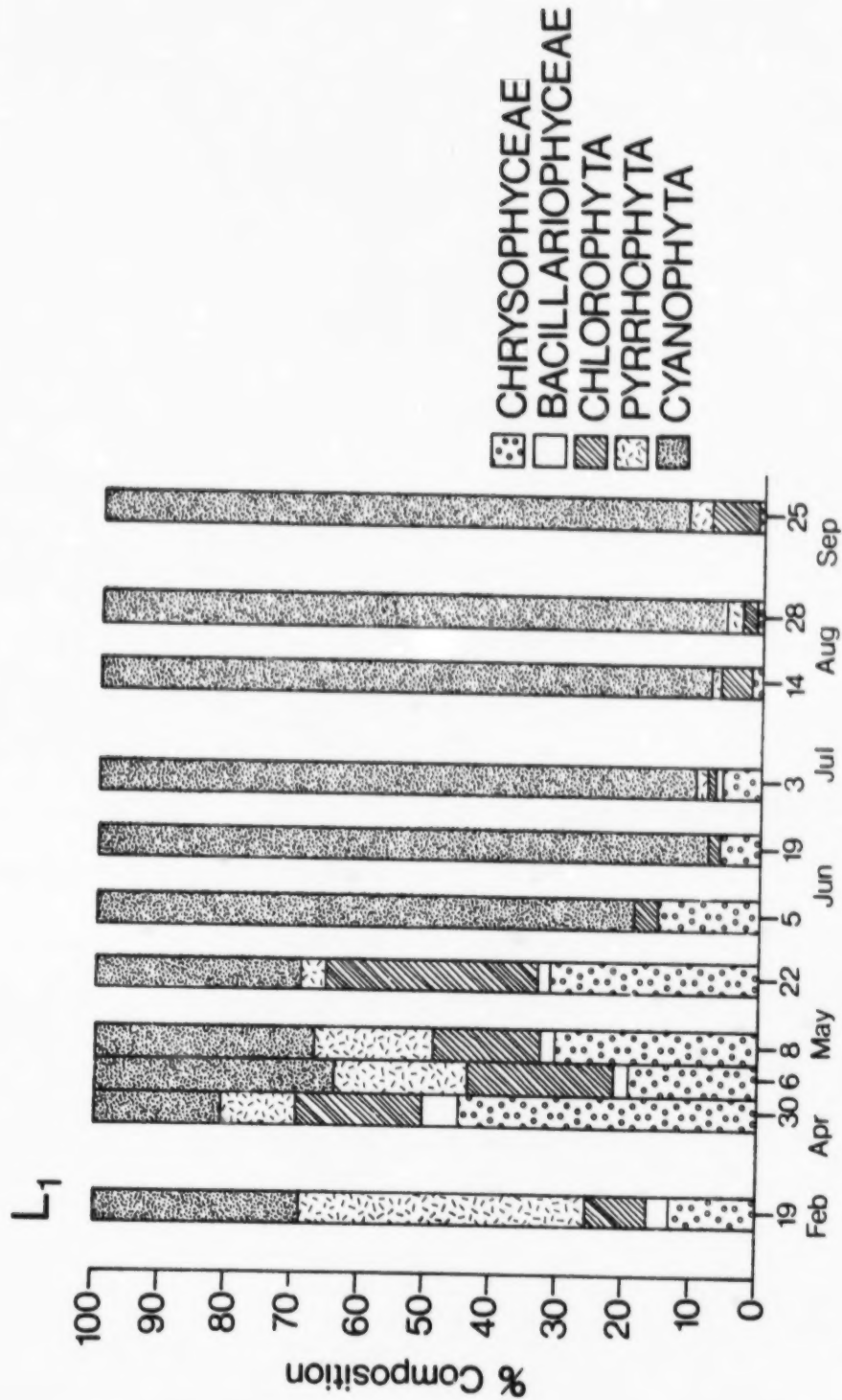


Fig. 7. Seasonal changes in phytoplankton composition for Lake L1, 1980

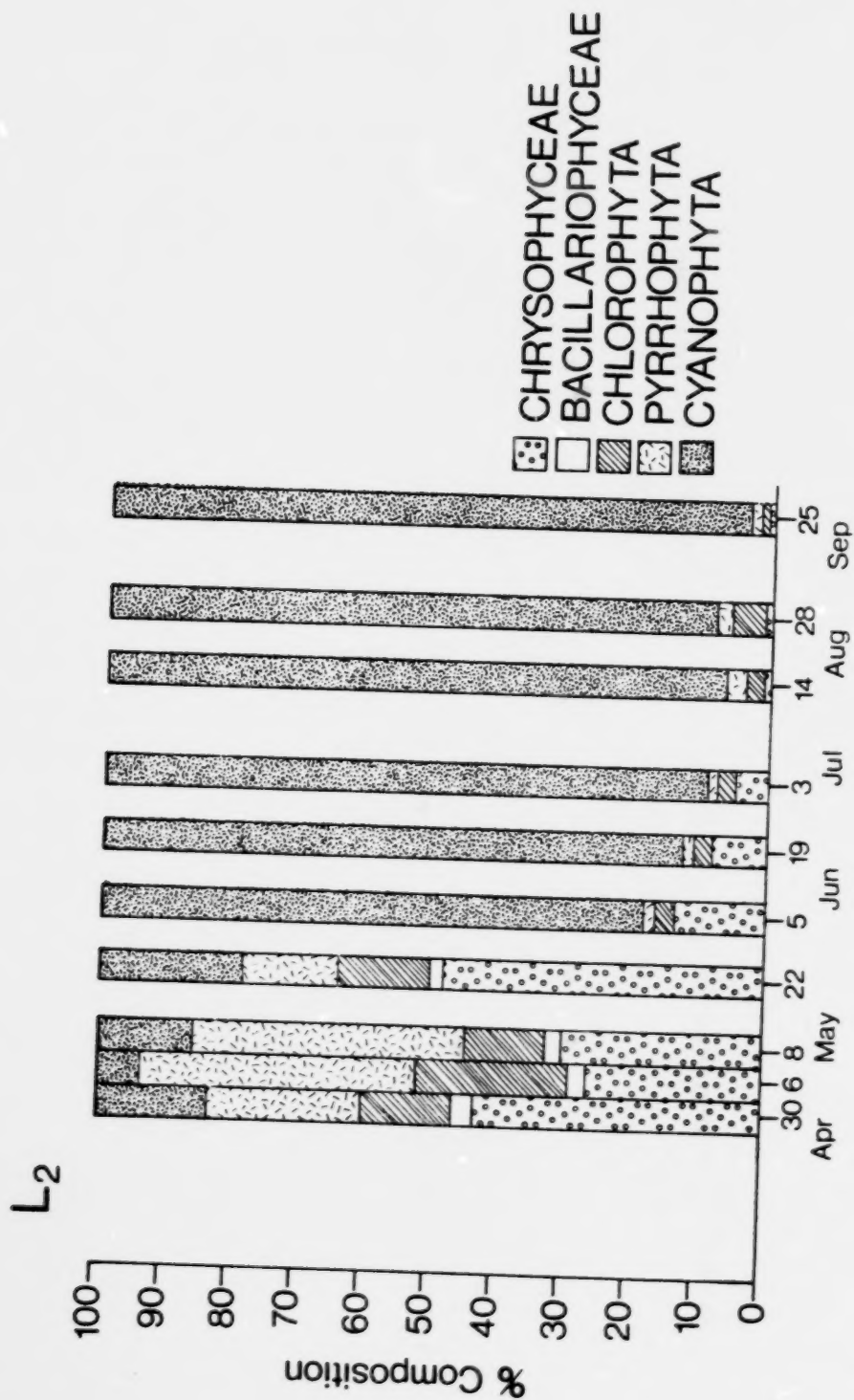


Fig. 8. Seasonal changes in phytoplankton composition for Lake L2, 1980

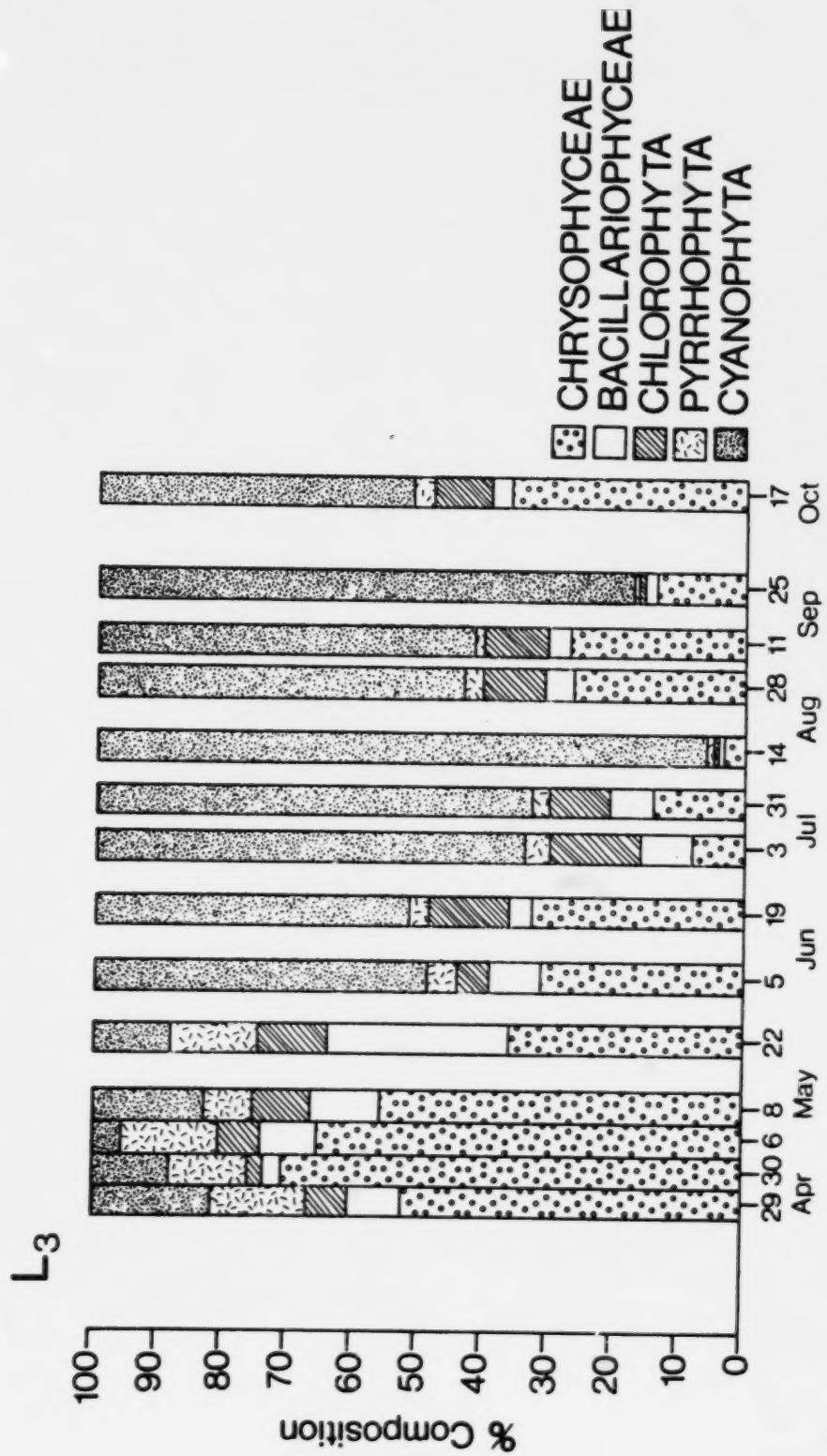


Fig. 9. Seasonal changes in phytoplankton composition for Lake L3, 1980

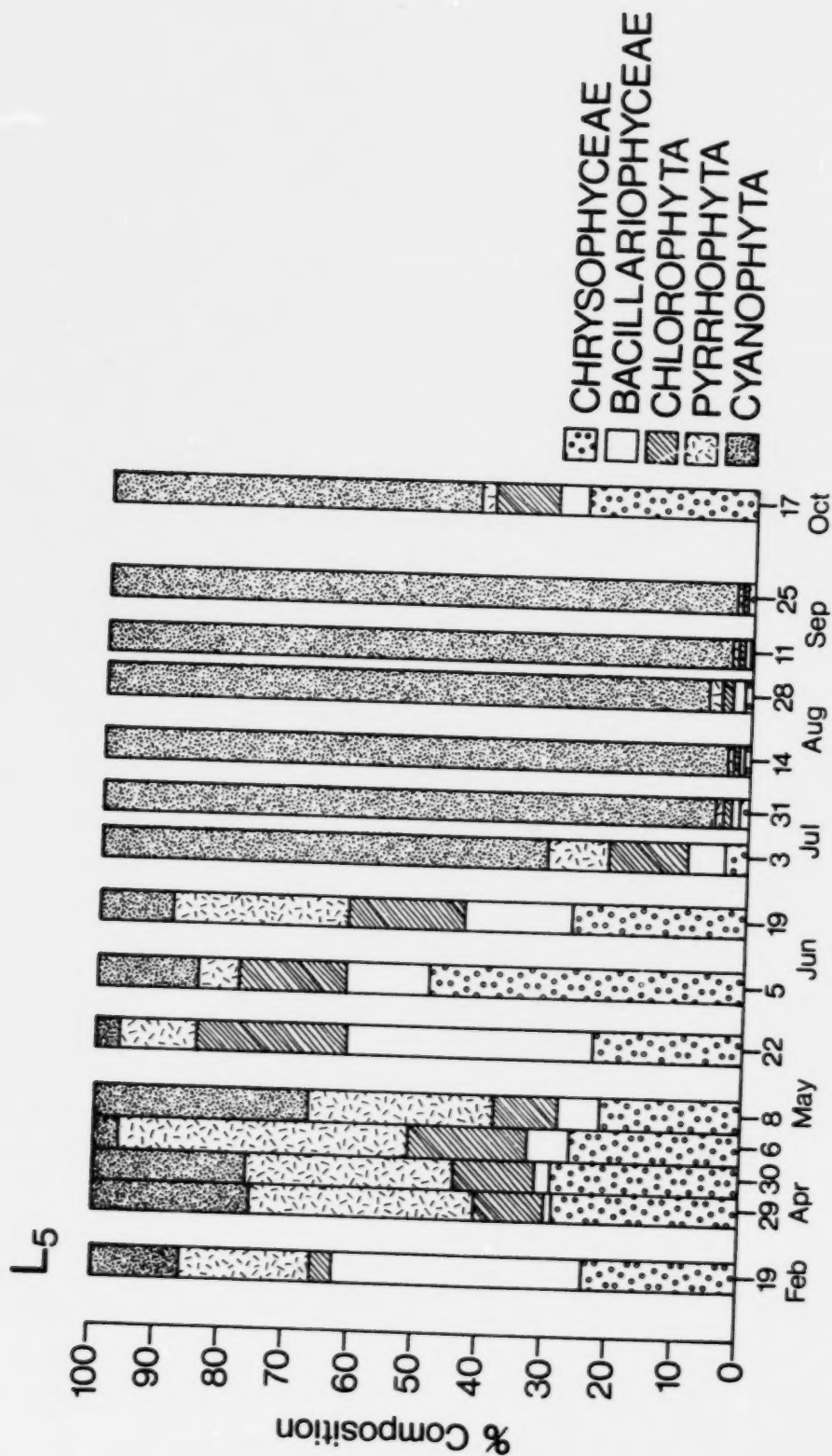


Fig. 10. Seasonal changes in phytoplankton composition for Lake L5, 1980

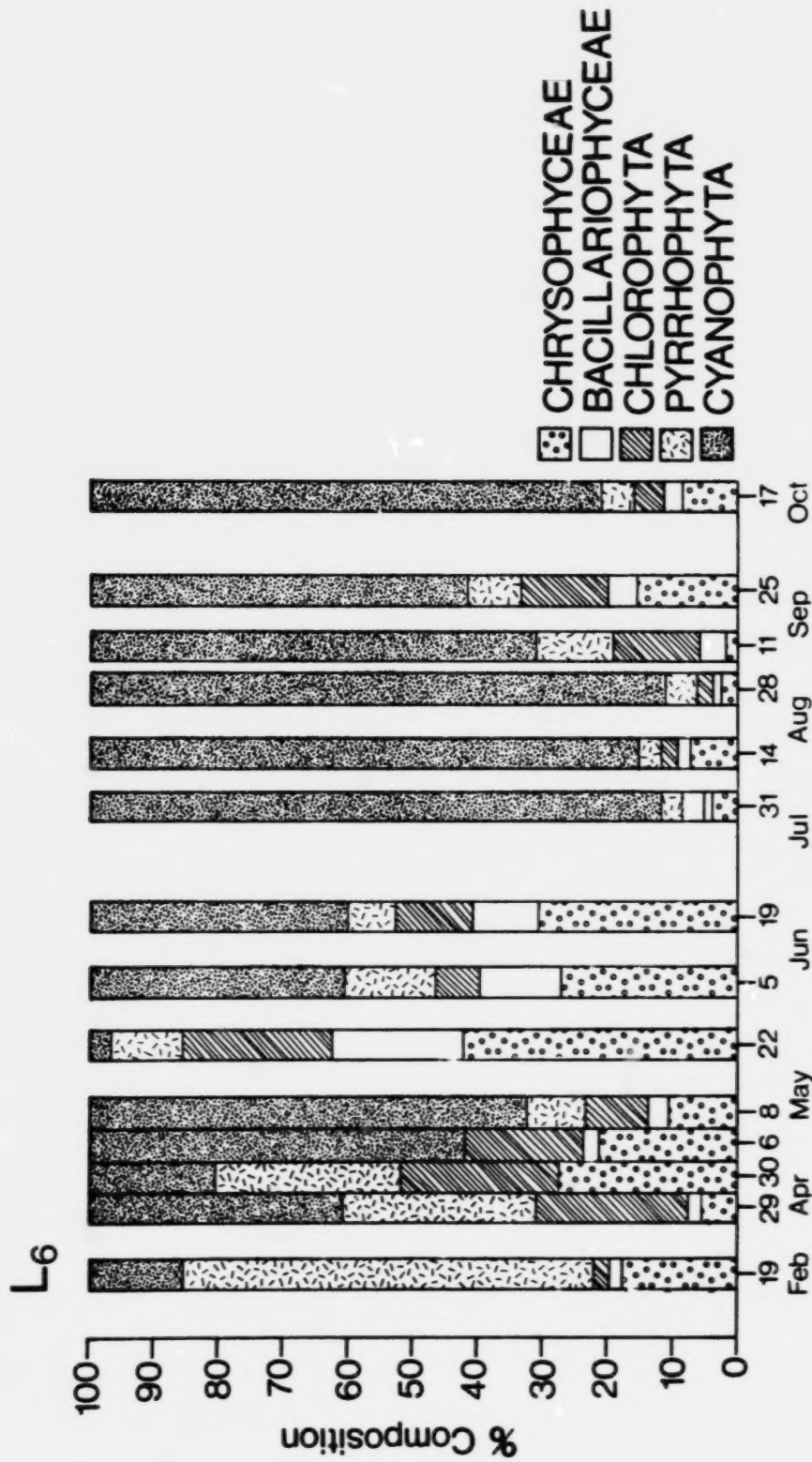


Fig. 11. Seasonal changes in phytoplankton composition for Lake L6, 1980